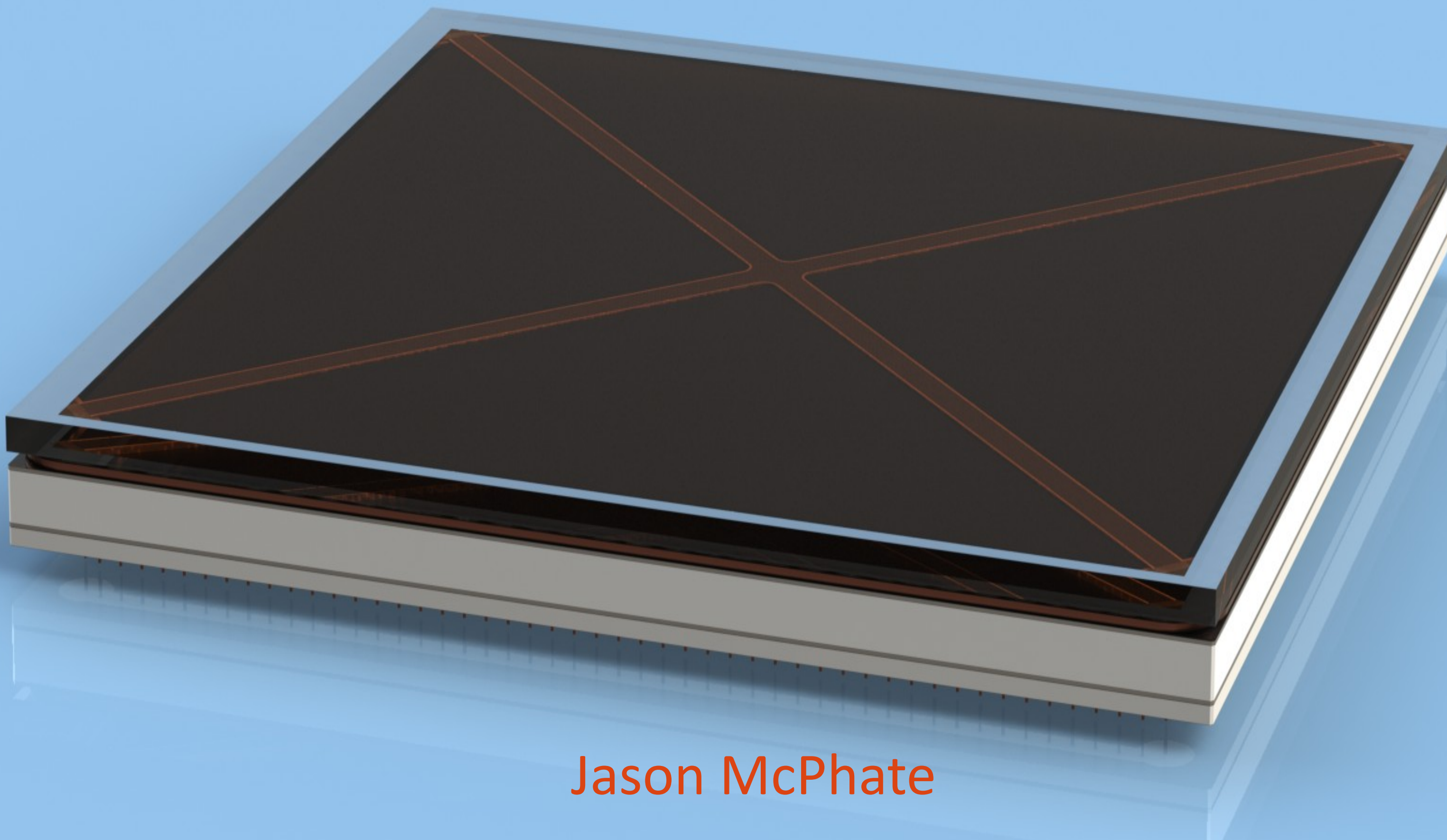
8” Ceramic Package Design & Processing



Jason McPhate

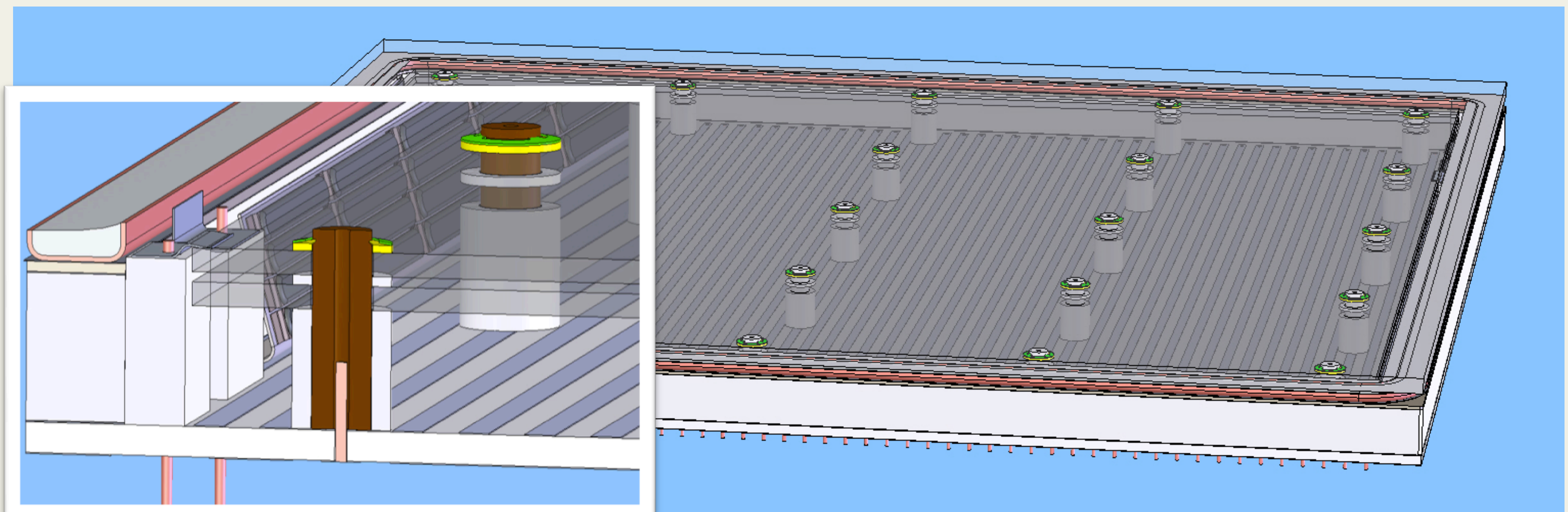
LAPP Hermetic Packaging Godparent Review

26 April 2011

Version 'C2' Tube Design Columnar Supports

- 25x anode-to-window columns (3mm diam) for mechanical support
- Collars for MCP support
- Pins through anode to locate columns
- Baseline anode .060" thick
- 132 holes in anode

- Advantages
  - Open pumping to getters at side of tube
  - No load borne by MCPs
- Disadvantages
  - Heavy load on columns
  - Localized stress on anode and window
  - Lots of parts for assembly

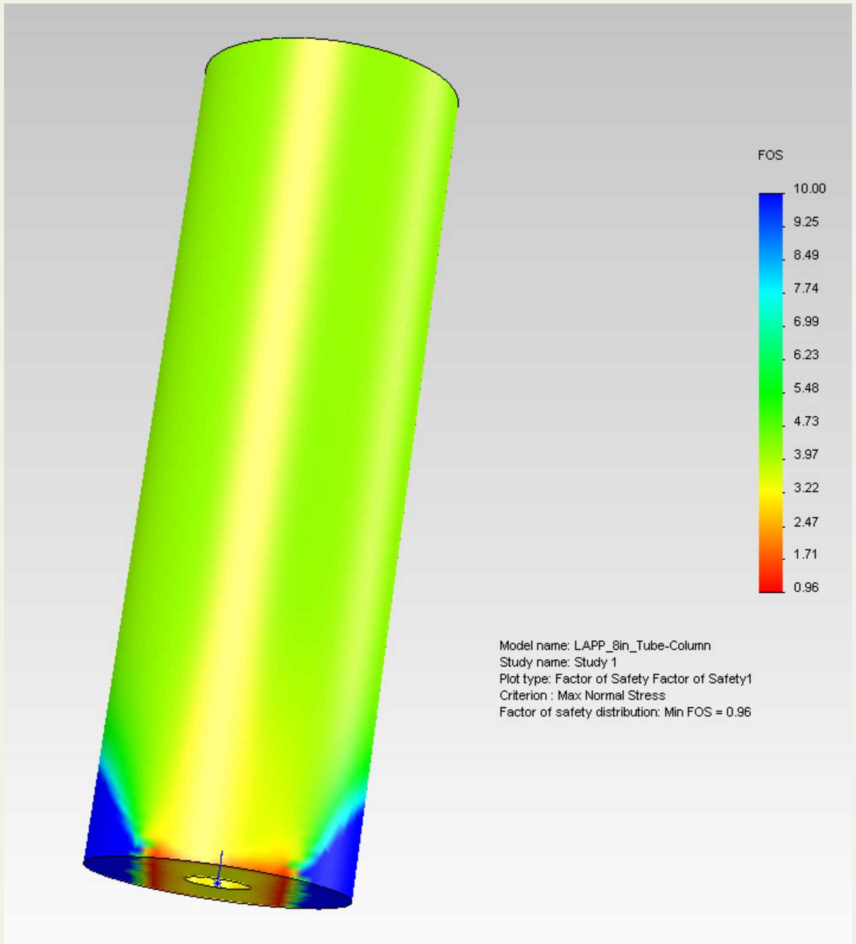


Yet Another Design
Revision D (aka the X-Tube)

- Principal differences from ‘C2’ concept tube
  - Replaced internal array of columnar supports with “X” shaped spacers
  - Added Kovar flange between anode and walls
  - Thickened anode substrate from .060” to .100”
  - Thickened window from 2.5 mm to 5.0 mm
- Motivation for design modification
  - Mechanical analysis of columns – too close to failure, especially where load concentrated by anode traces
  - Worried about stress loading on anode, just where the holes for the column locating pins were placed
  - Small defects in window caused by column scratching could cause failure

Analysis of ‘C2’ Support Column

- Total area of 25 columns = 0.27 in^2
- Needs to support large fraction of 1000 lbf (atmosphere)
- 100 lbf load on top (uniform) – a bit more than 2x atmospheric load on column
- Bottom support localized to area of anode trace width
- Design factor of safety (FOS) near anode loading at or below 1 – *bad*



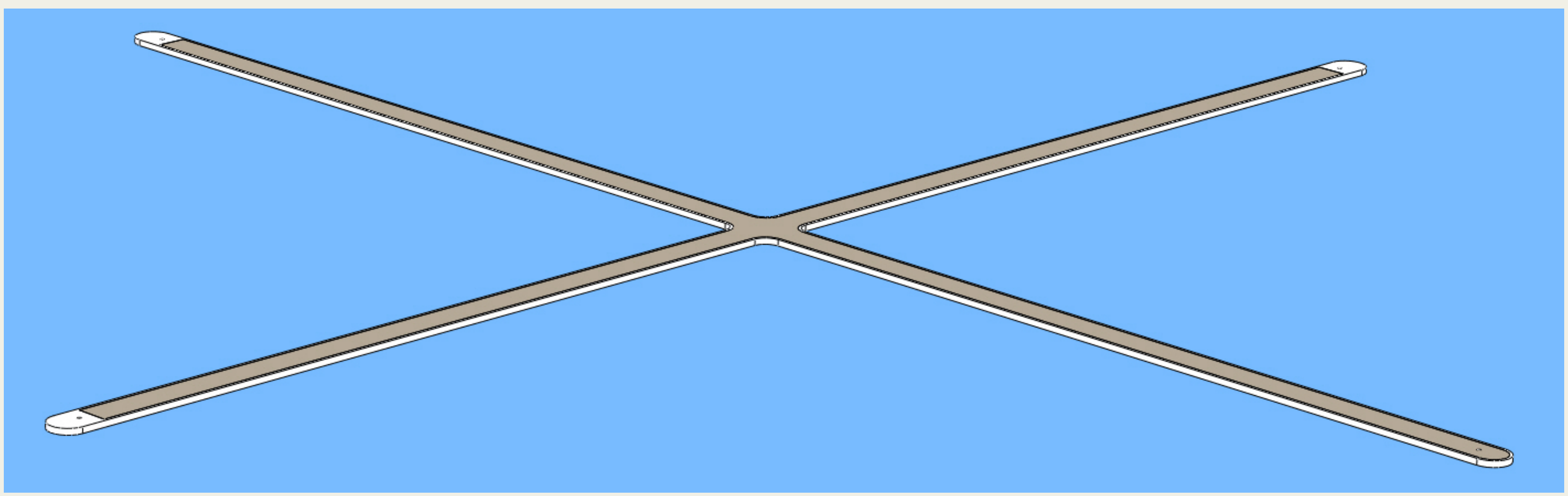
"X"-Grid Spacer Concept

- Design Goal: Maintain good internal pumping while reducing stress on mechanical supports
  - More distributed load design using the MCPs as part of mechanical stack – like the square grid spacers
  - But eliminate enclosing edges to allow venting (no large, active trapped volumes)
  - Support corners of MCPs to minimize mechanical flexure

What's left is an "X" shaped spacer crossing the MCPs from corner to corner.

X-Grid Spacers

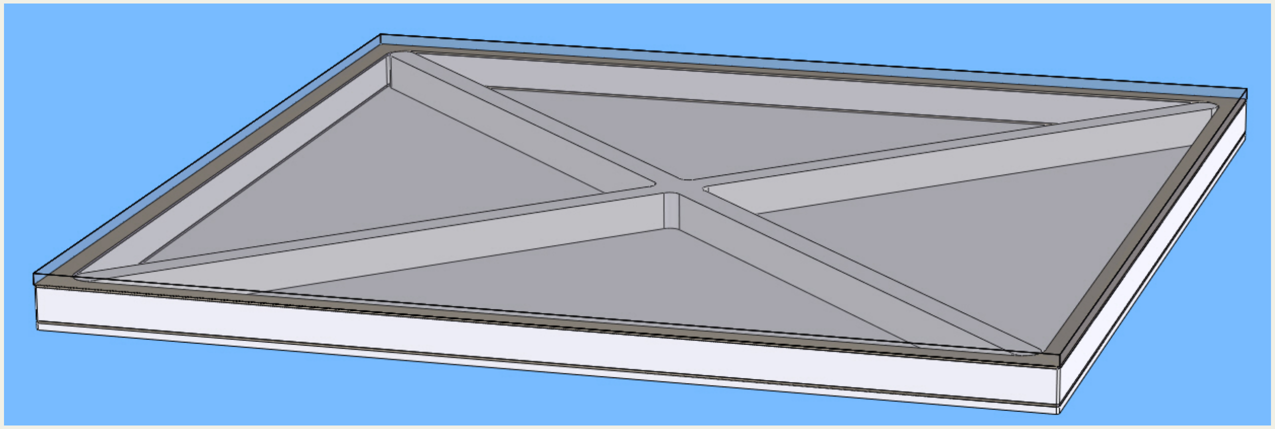
- Material: 96% Alumina
- 0.25” wide -> total area 5.26 in^2 (compare to 7.75 in^2 for square grid)
- 1 mm thick spacers for cathode and inter-MCP gaps
- 2x .120” (6.1 mm) for anode gap
- Reduces internal assembly from >100 parts to just 6
- Added bonus of being used for HV distribution and MCP hold-down
- But can the window and anode support such large open areas?



Simplified X-Tube for Analysis

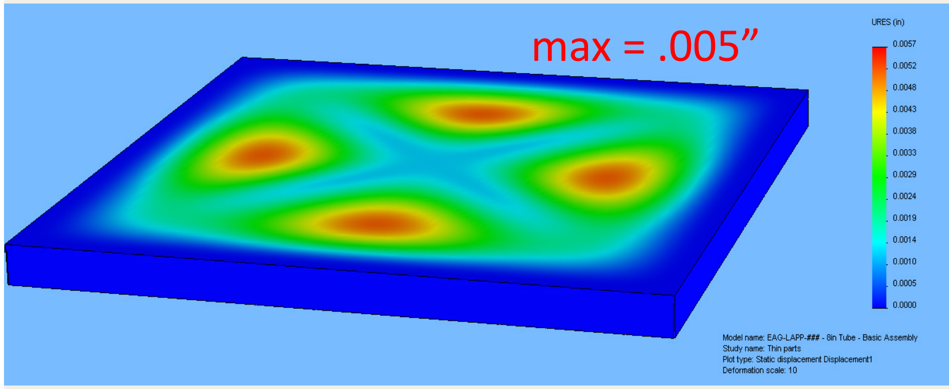
- Eliminate difficult-to-model stamped indium well (still working on this one)
- Eliminate MCPs as their compressive strength is not known (yet)
- Single, tall X-grid to replace full internal stack
- X-grid .003” shorter than external stack height
- Assume 25 Mpa for window tensile/ultimate strength (Schott number)

- Apply 15 psi to both sides, look at deformations and stresses

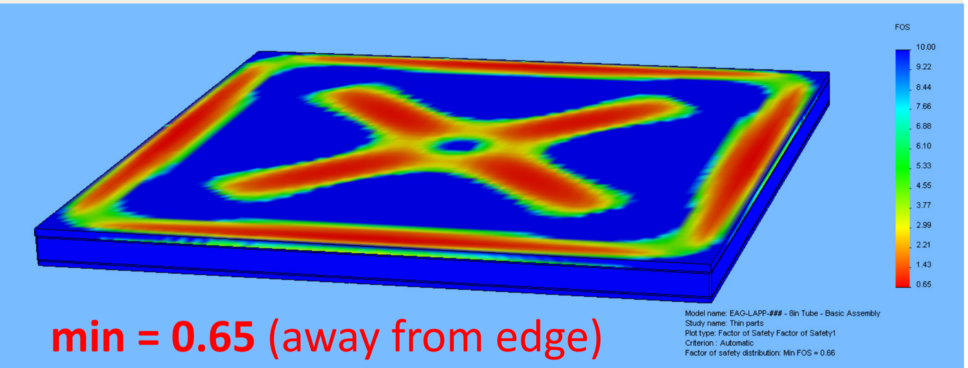


Simplified X-Tube Analysis
2.5 mm Window, .060” Anode

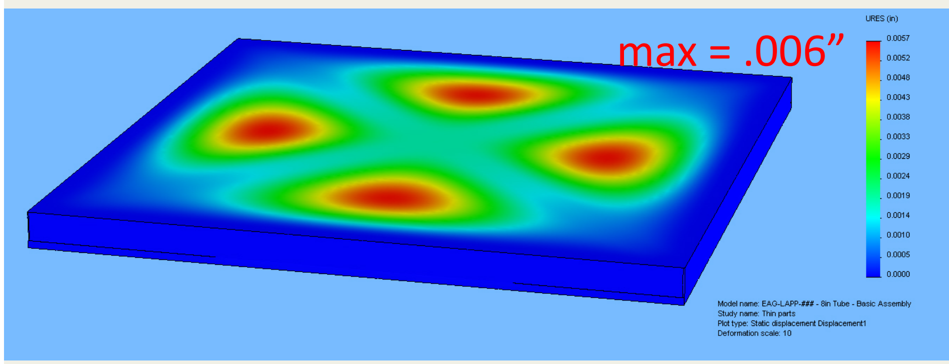
10x Window Deflection



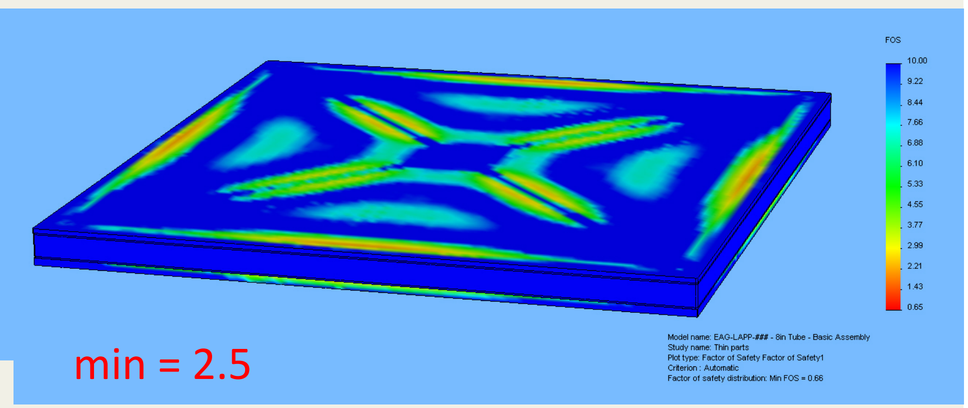
Window Factor of Safety



10x Anode Deflection

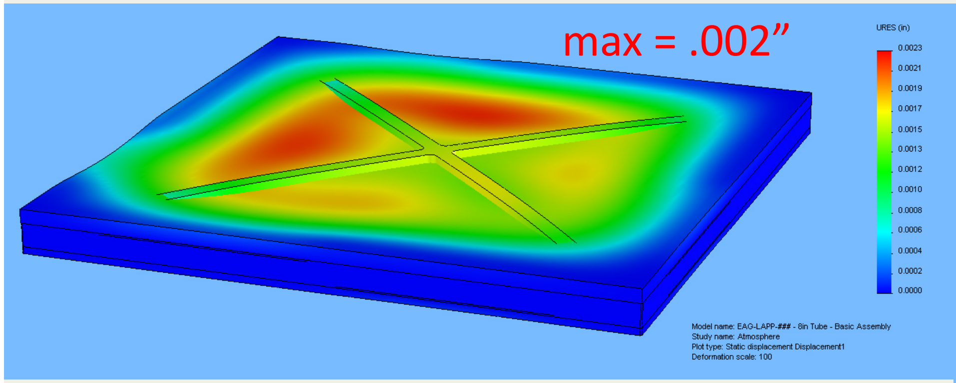


Anode Factor of Safety

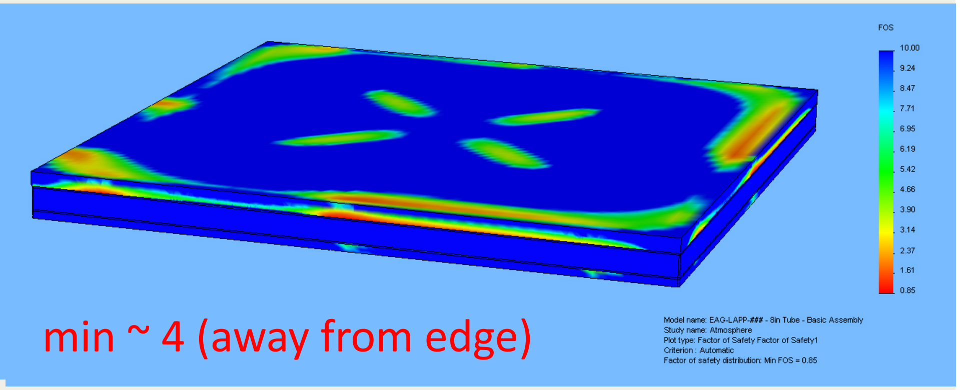


Simplified X-Tube Analysis
5.0 mm Window, .100” Anode

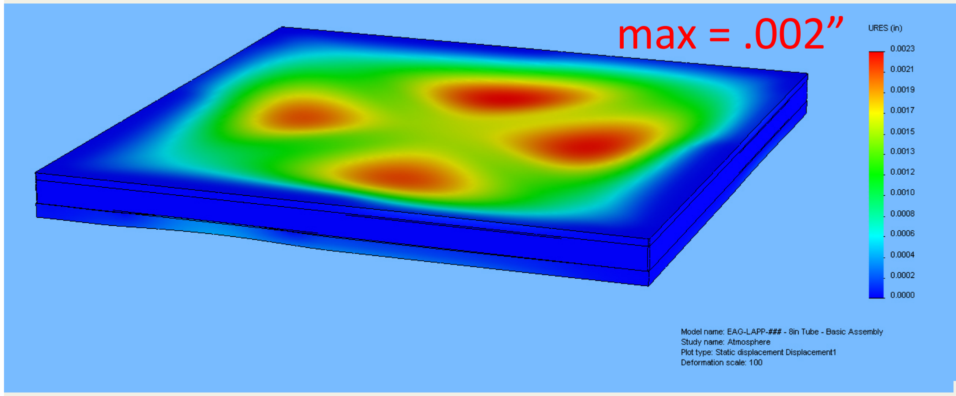
100x Window Deflection



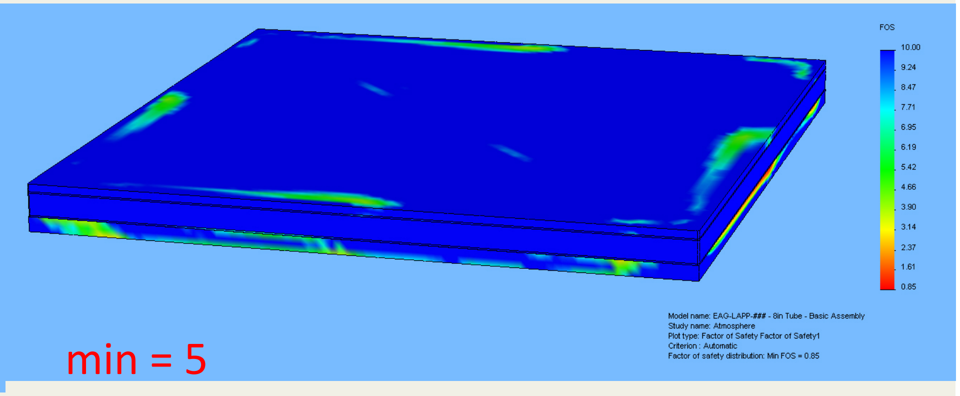
Window Factor of Safety



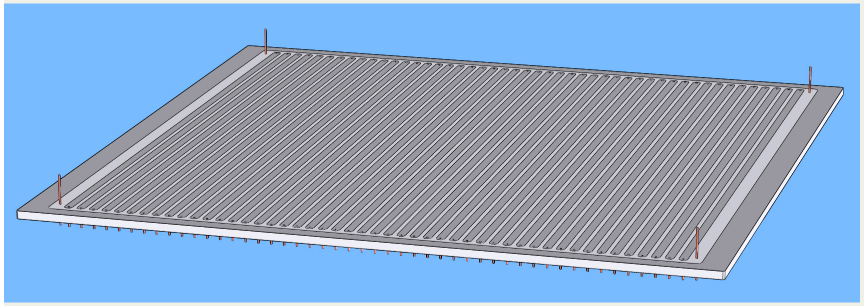
100x Anode Deflection

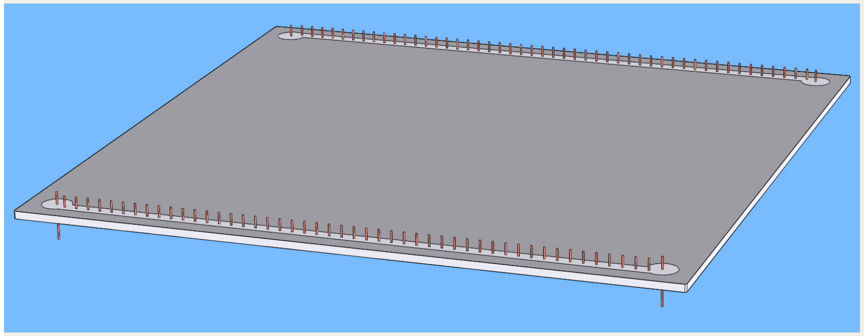


Anode Factor of Safety



Anode Design





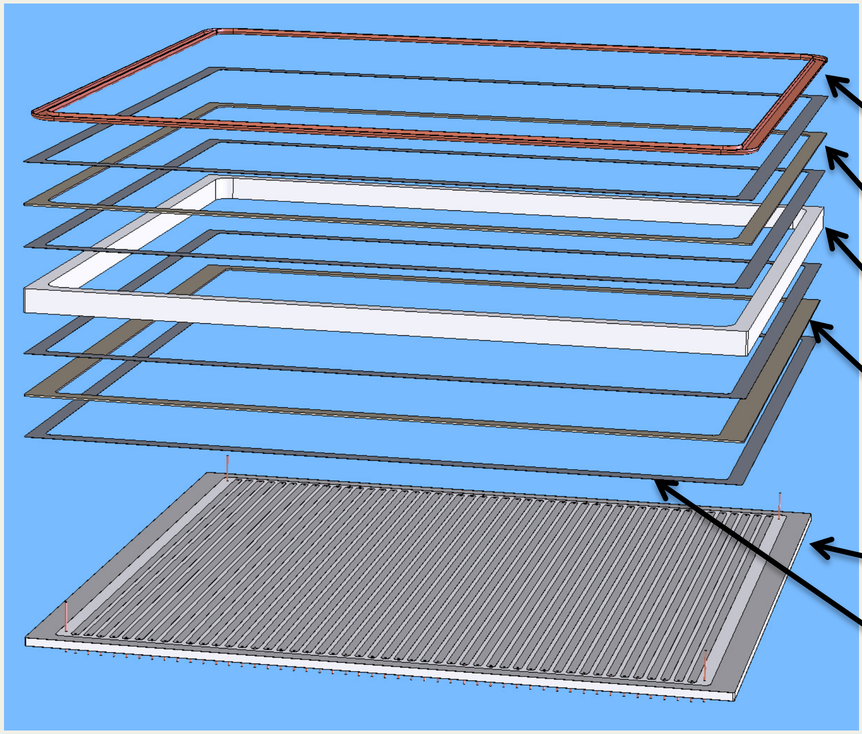
- .100” thick 96% alumina substrate, laser cut edges and pilot holes for signal/HV pins
- Diamond grind edges and ream holes to final size – eliminates stress cracking and cleans up edges
- W, Mo-Mn metallization – HiTemp process (fired at 1450°C)
- Interior
  - 48x .100” wide strips on .160” pitch
  - Solid metallization border for braze
- Exterior
  - Essentially complete ground plane
- All metal surfaces electrolessly plated with Ni
  - Subsequent electroplating with Au or Ag if needed for conduction
- Cu plated Kovar pins brazed into holes with CuSil washers (850°C braze) – 96 signal, 4 HV

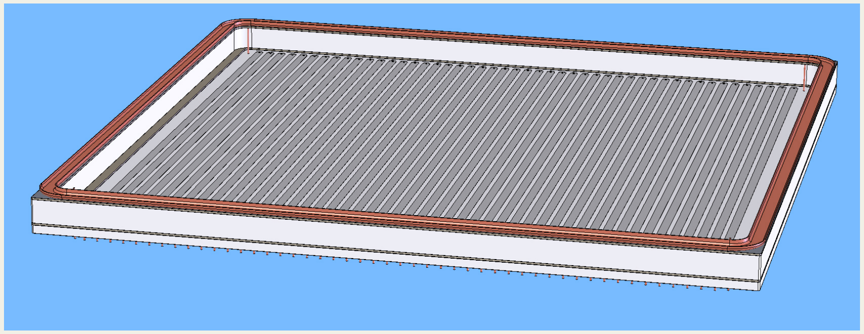
Anode Status

- 10” x 10” x .100” alumina substrates ordered from CoorsTek (QTY 20 @ $162ea) – Expected end of May
- Awaiting results of strip impedance testing on test substrates (4.5” sq, .100” thick) to finalize strip design

- Then to laser cutter and final machining before metallization and pin brazing
- Need braze tooling to control pin heights – design and fab

Brazed Body Assembly



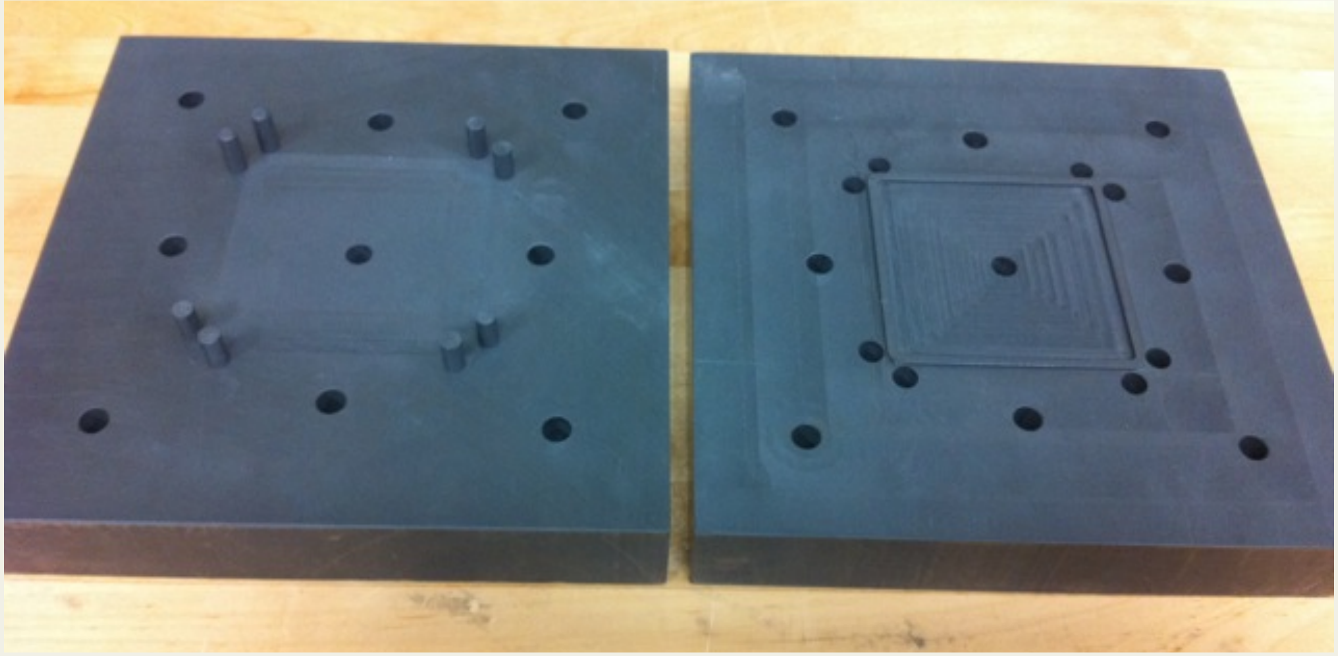


- Single step braze
  - Stamped OFHC Cu or Kovar indium well
  - Kovar intermediary flange
  - Alumina wall
  - Kovar getter flange
  - HiTemp, CuSil brazed anode
- InCuSil braze alloy (750°C braze)
  - Avoids remelt of anode CuSil
- Four braze joints in final assembly

Status of BBA Pieces

- Windows
  - Thickened to 5 mm
  - 10 in house
- Anodes
  - Thickened to .100”
  - 20 substrates end of May
  - Awaiting impedance test results for final design
- Indium wells
  - 103 OFHC Cu in house
  - Deep draw Kovar ordered for 20 more
- Kovar flanges
  - Top flange fabbed and Ni-sintered
  - Bottom flange designed
- Ceramic walls
  - 20 received
  - 2 metallized for braze(~.050” warping)
  - 5 post-machine fired (no warping)
- InCuSil braze preforms
  - Material only to 6” width
  - Make frames by dovetailing corners of 5mm wide strips
- Braze tooling
  - Needs designing and fabrication
  - Will be based on successful Planacon jig

Planacon Braze Tooling

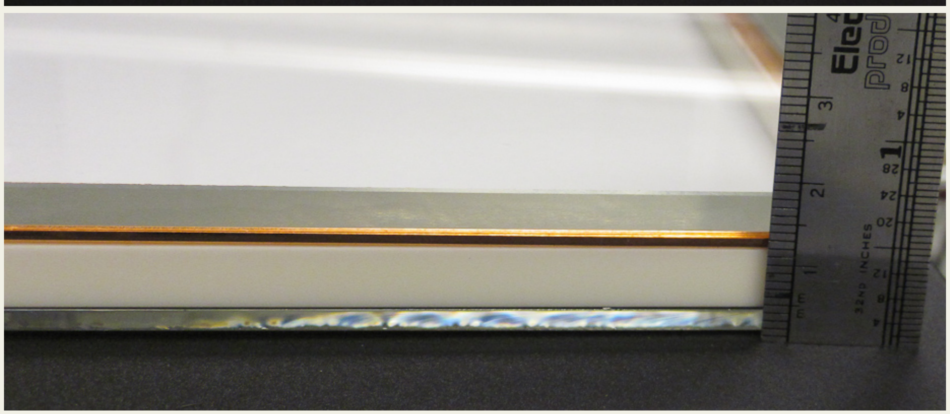


Base, with corner locating pins

Top, with ridge to press into In well

- Graphite to reduce sticking of braze run-out
- Stack components on base, aligned by pins
- Stack on top and add weight
- A similar design for LAPP, with recesses for the anode pins

Illustrative Tube Stack



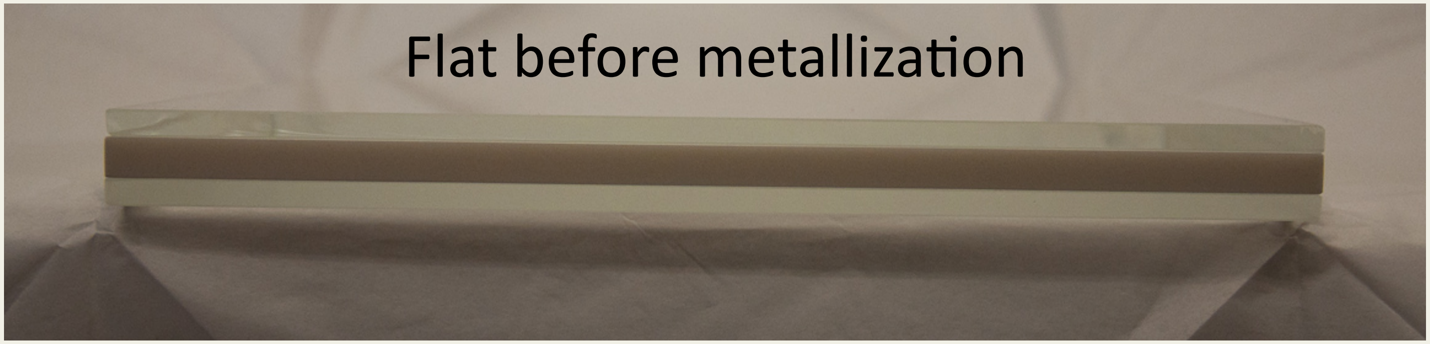
Stack of:

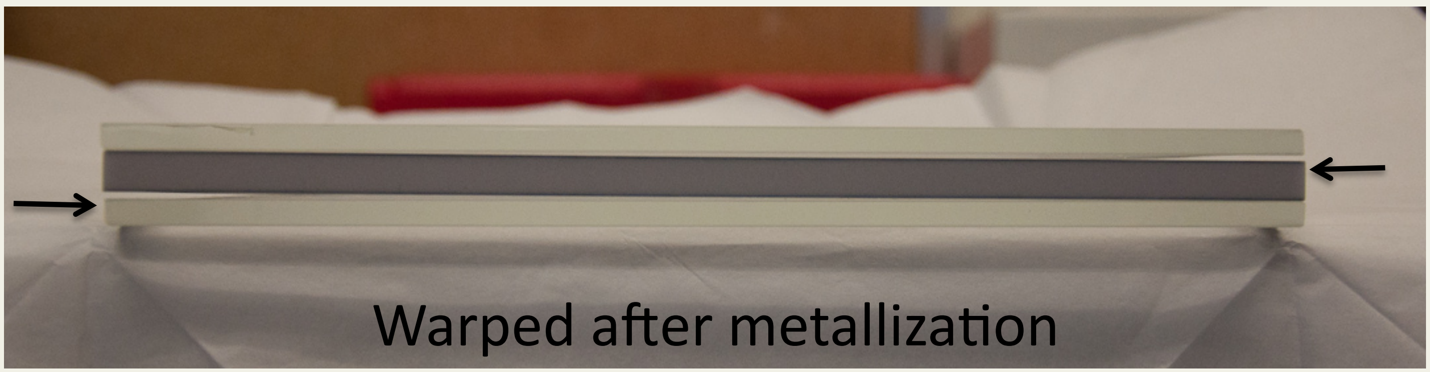
- 2.5 mm window as “anode” blank
- Ceramic wall
- OFHC Cu indium cup
- 5 mm window

- Missing Kovar flanges (add 1mm)

- Total stack height will be ~20 mm

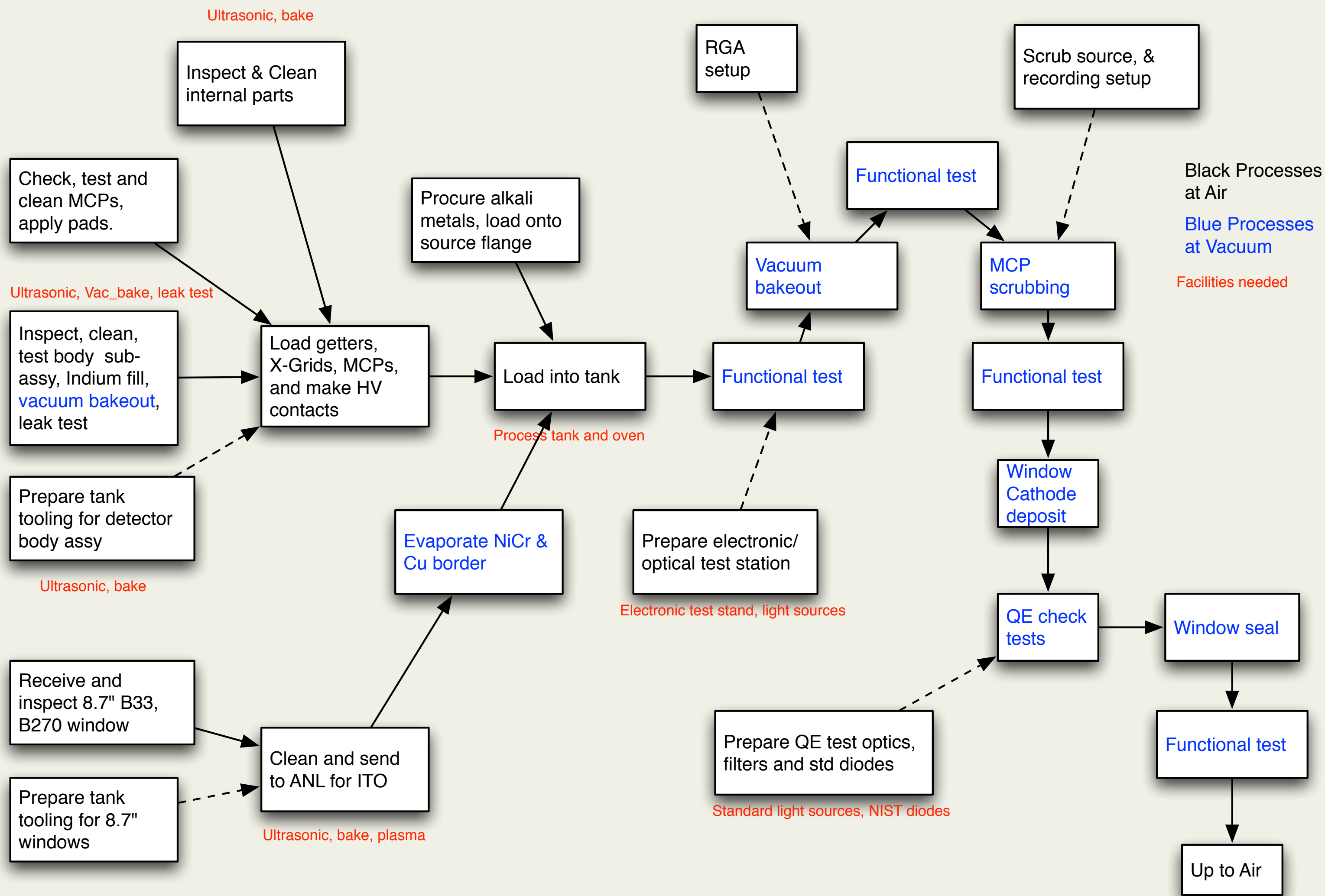
Warped Ceramic Walls





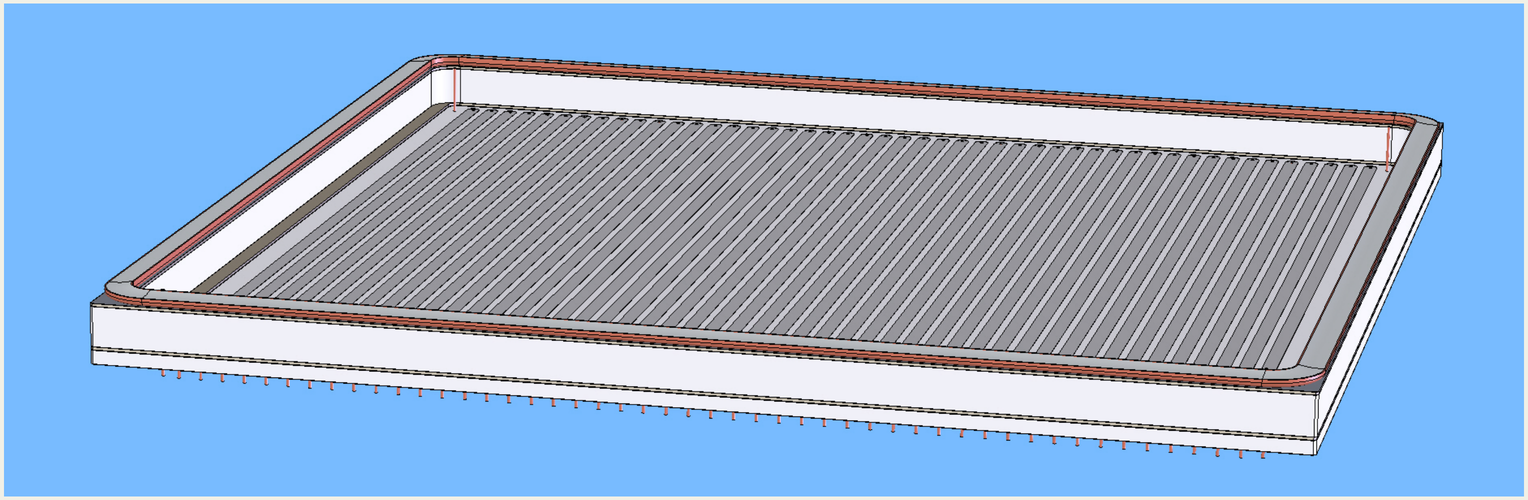
- Several attempts (re-fired with pressure) to flatten the warped frames failed
- Pre-metallized frames fired with same thermal profile do not warp
- Can be pressed flat with modest force (5-10 lbf)
- Will attempt braze with warped parts and see what happens

8” Tube Process Flow



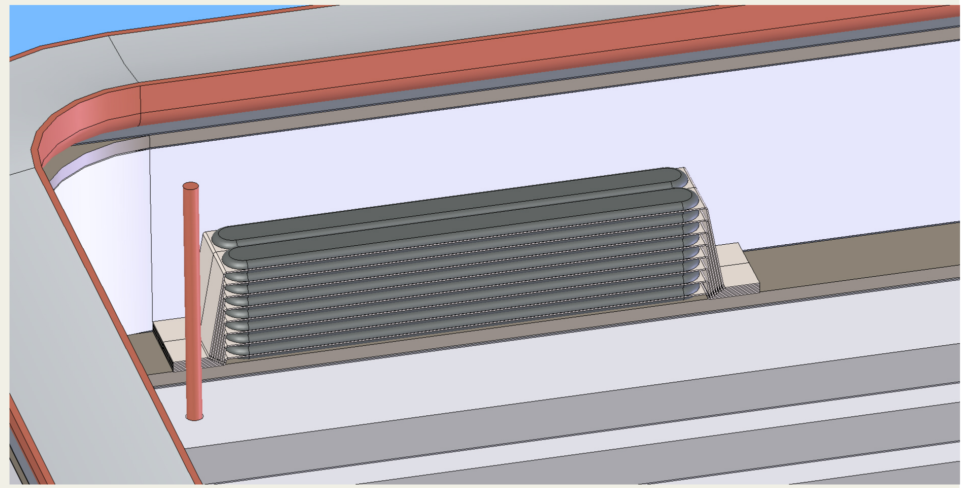
BBA Pre-Process Preparation

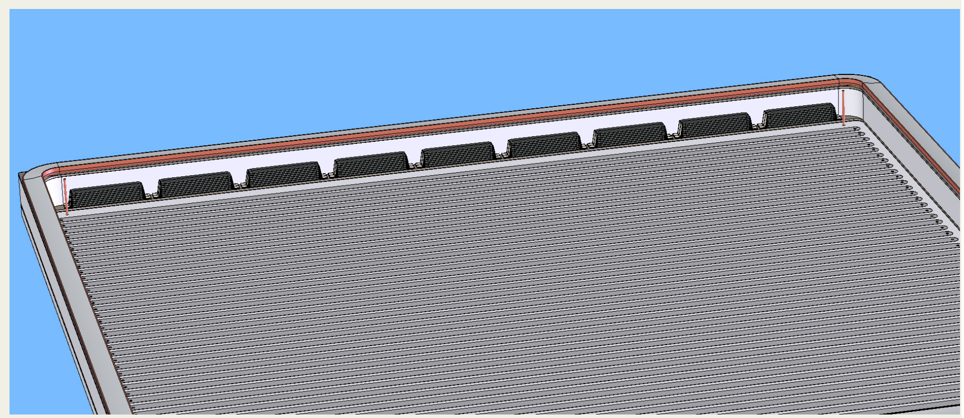
- Leak check (requires support jig)
- Load InBi alloy in cup
- Remove indium oxide
- Vacuum bake to outgas indium (chamber made, needs build-up)
- Leak check (first assembly bake)
- More oxide removal if needed
- Install getters
- Ready for tube build



Getters

- SAES St-122 getter strips
  - Getter material bonded sintered onto .002" Ni shim
  - Passively activated by 350°C tube processing temperature
- Spot weld strips down to bottom Kovar flange
- Total of ~300 getter strips
  - N_2 pumping speed ~30 l/s, (CO & H_2 better)
  - Using Dean's 8" MCP outgassing rate -> tube pressure ~ 10^{-10} torr
- Robust design, if labor intensive
- Top getters well clear of bottom MCP





Tube Internal Parts Preparation

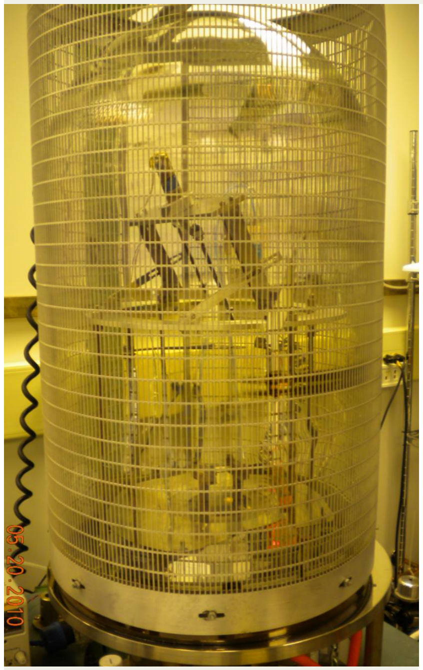
- MCPs get standard treatment
  - Ultrasonic clean in 50/50 Iso/Methyl mixture
  - Air bake to dry (~100°C)
- Other bits (X-grids, HV contacts, etc.)
  - Standard wet clean process
    - Ultrasonic in Valtron/DI water mix
    - DI water rinse
    - Ultrasonic in DI water
    - Ultrasonic in isopropanol
    - Air bake to dry (~100°C)
- Alcohols are Nano-Grade to minimize residues and particulates

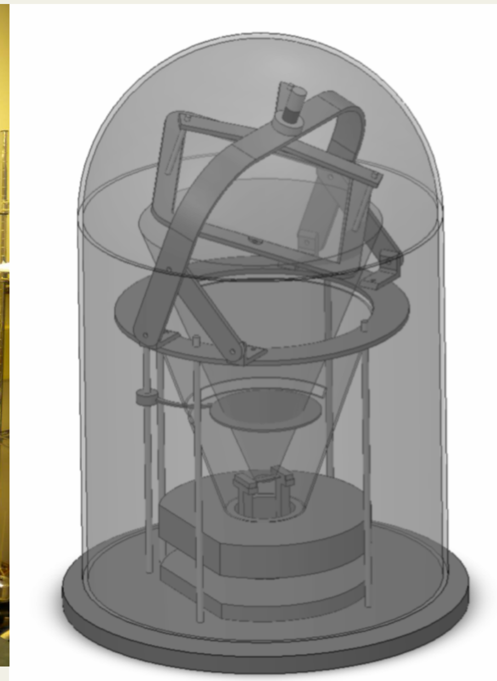
Window Preparation

Large plasma asher installed in clean room.

- Standard wet cleaning
  - Add mechanical scrubbing with calcium carbonate slurry to get water break if needed
- Plasma clean

Window Preparation (cont)



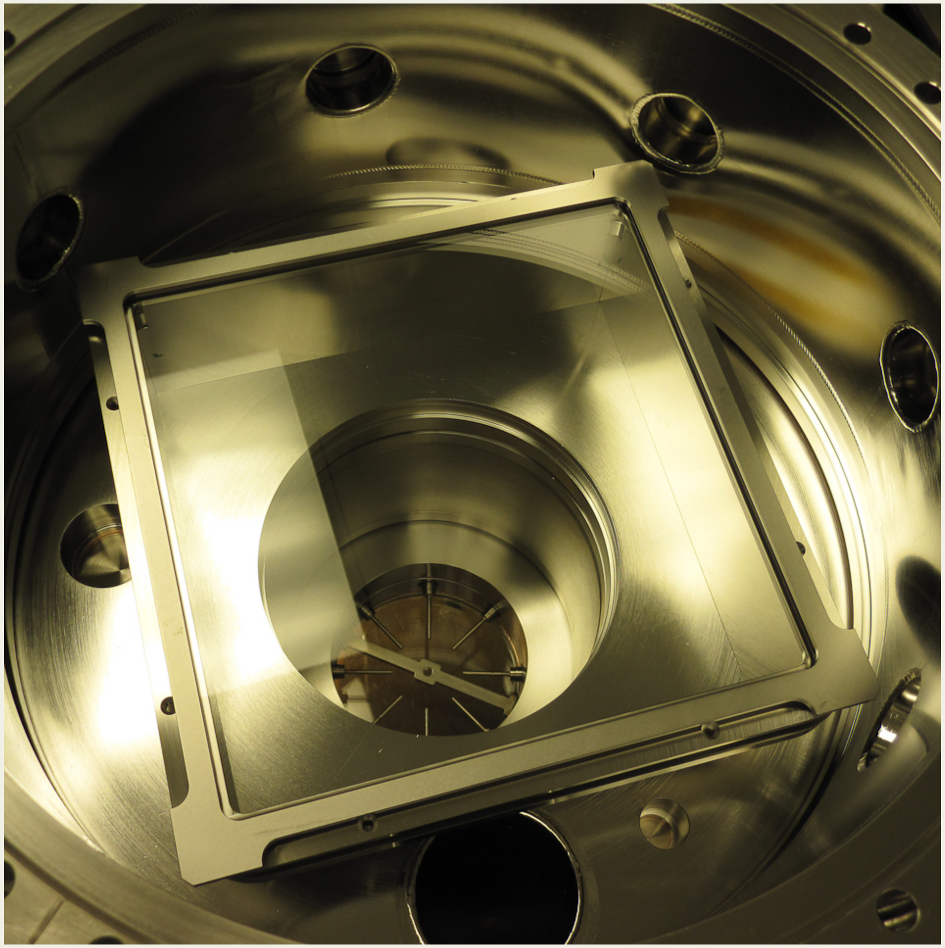


8.66" window deposition hardware fully commissioned and tested

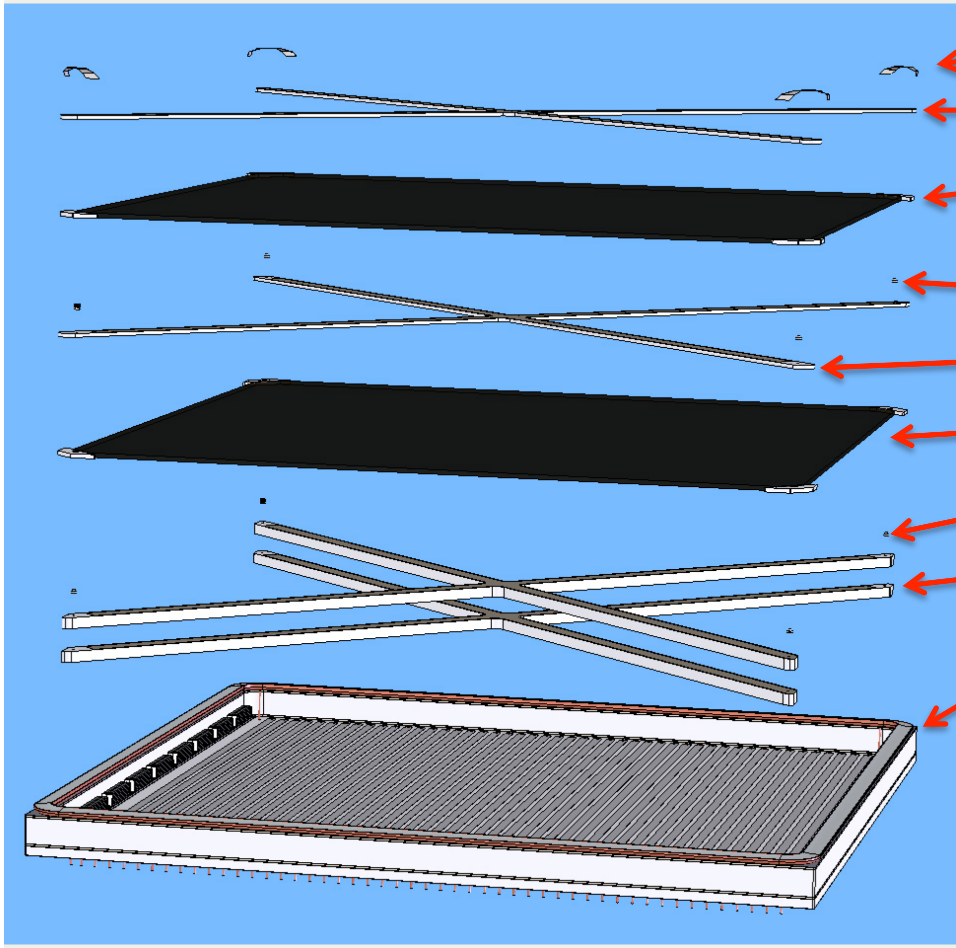
- Apply metallic border with sputtering system
  - NiCr first for adhesion to glass and photocathode contact
  - Possible NiCr grid for cathode conductivity
  - Cu next for indium seal wetting
- Install into transfer fixture
  - For manipulation in the process chamber
- Ready for installation in process chamber
  - Store in vacuum until ready to perform chamber load

8” Window Nest

- Window nest parts and handling fixture for the 8” cathode test chamber are in house.
- Same part will be used in the large tube process chamber
- Ceramic frame from BBA doubles as insulator in nest to allow biasing of cathode during deposition



Internal Stack Assembly



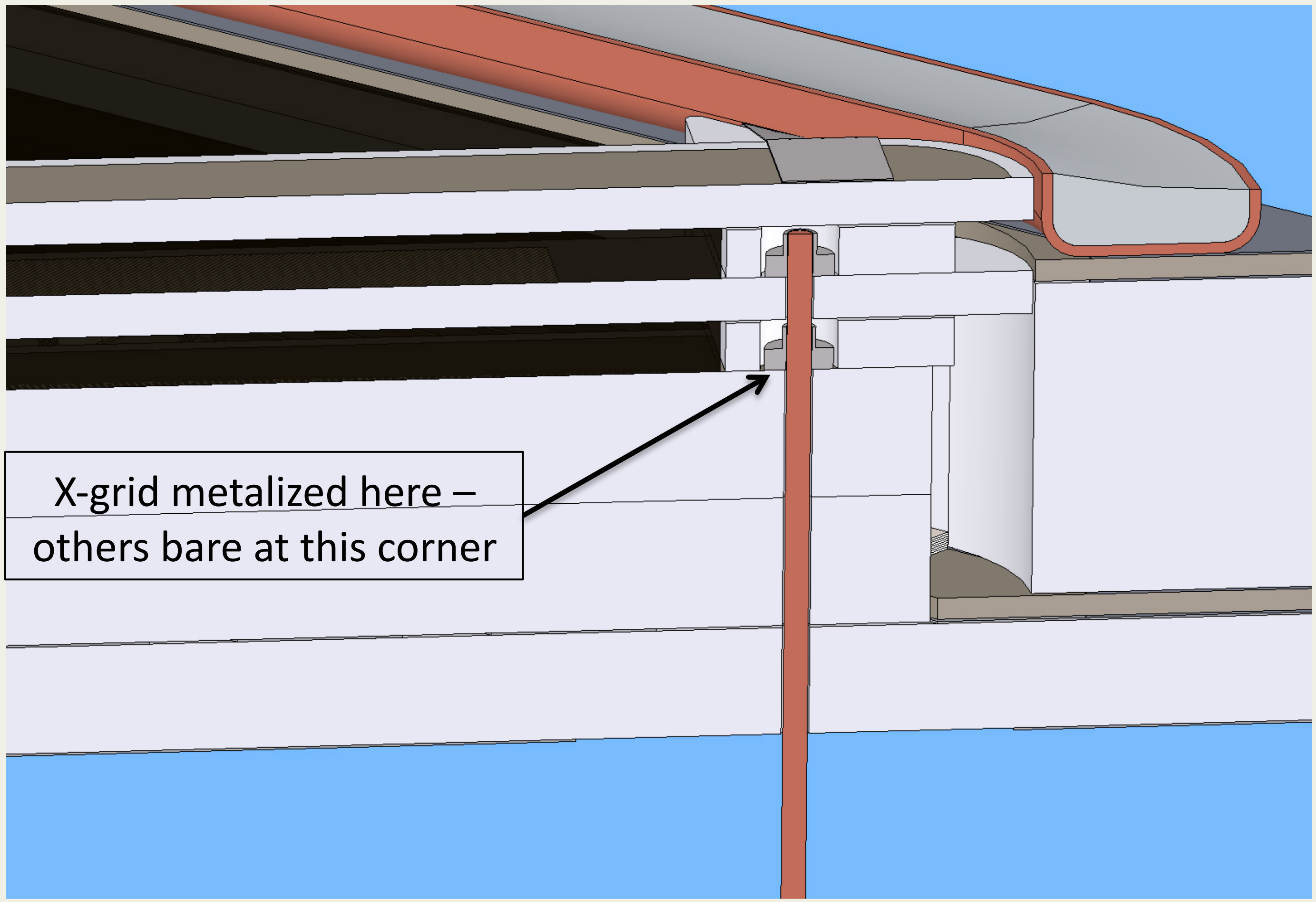
- Stack hold-down straps
- Top X-Grid – 1 mm thick
- Top MCP – with anti-rotation blocks at corners
- HV contacts
- Middle X-Grid – 1 mm thick
- Bottom MCP (w/ A-R blocks)
- HV contacts
- Anode gap X-Grids - .120" ea
- Prepared BBA (indium and getters)

- Internal stack height .003" shorter than walls to ensure seal

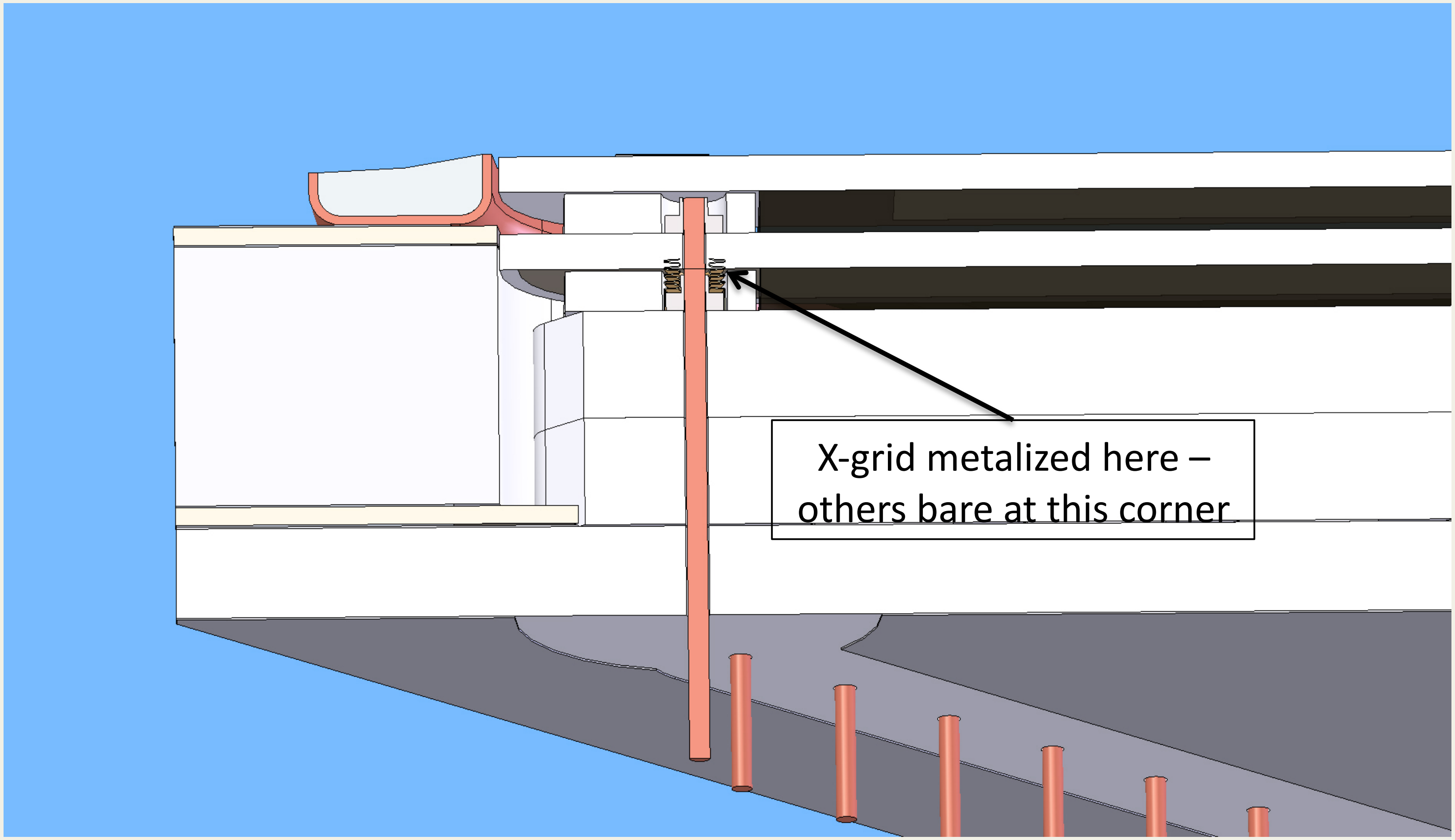
HV Contact Scheme

- Four HV pins through anode (one in each corner) for MCP HV's
- Cathode HV provided externally
- Each of the lower X-grids have locating holes in the ends of the arms
- Top-hat washer spot-welded to all pins at all levels to hold down stack
- Each X-grid is metalized (evaporated NiCr) and oriented to provide unique contact of each MCP surface to only one pin
- Contacts to MCP top surfaces (X-grid bottoms) made by miniature Ni bellow contact
- Top X-grid lacks holes to provide insulation between cathode and HV pins
- Top of stack "strapped down" to the top Kovar flange with two overlapping, spot welded .001" thick stainless shims (at all corners)

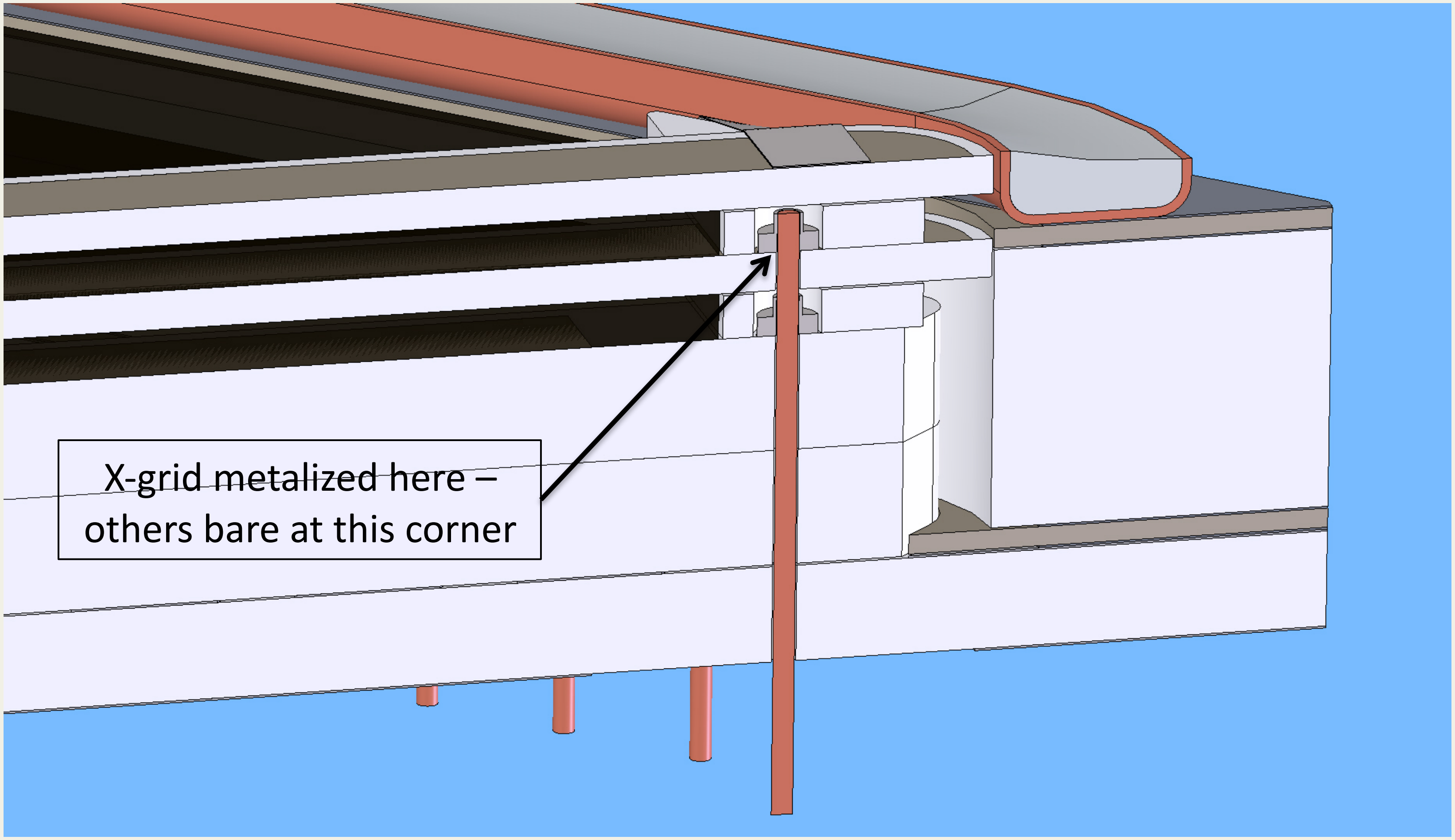
HV1 (Bottom) Contact Detail



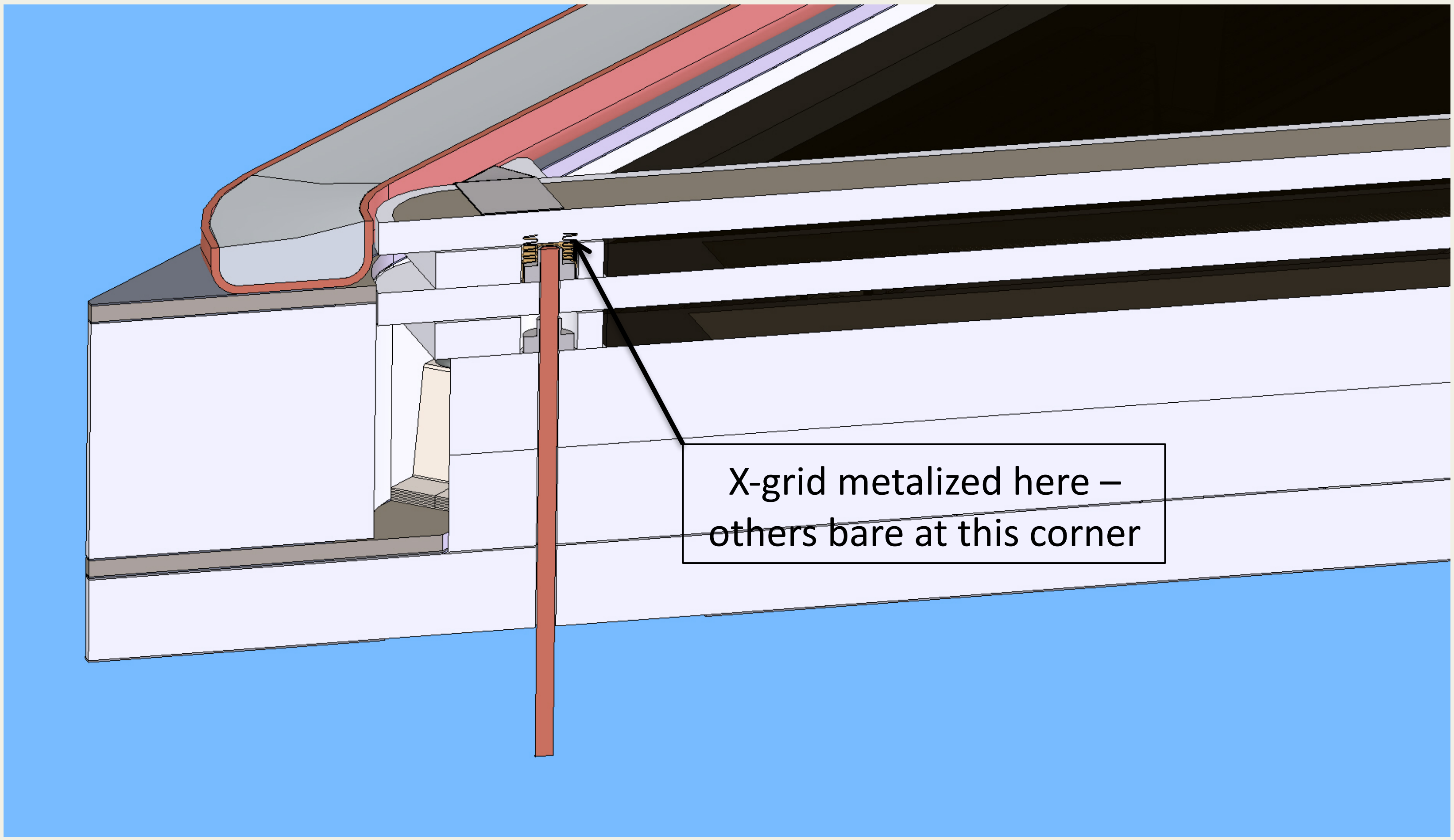
HV2 (Lower-Middle) Contact Detail



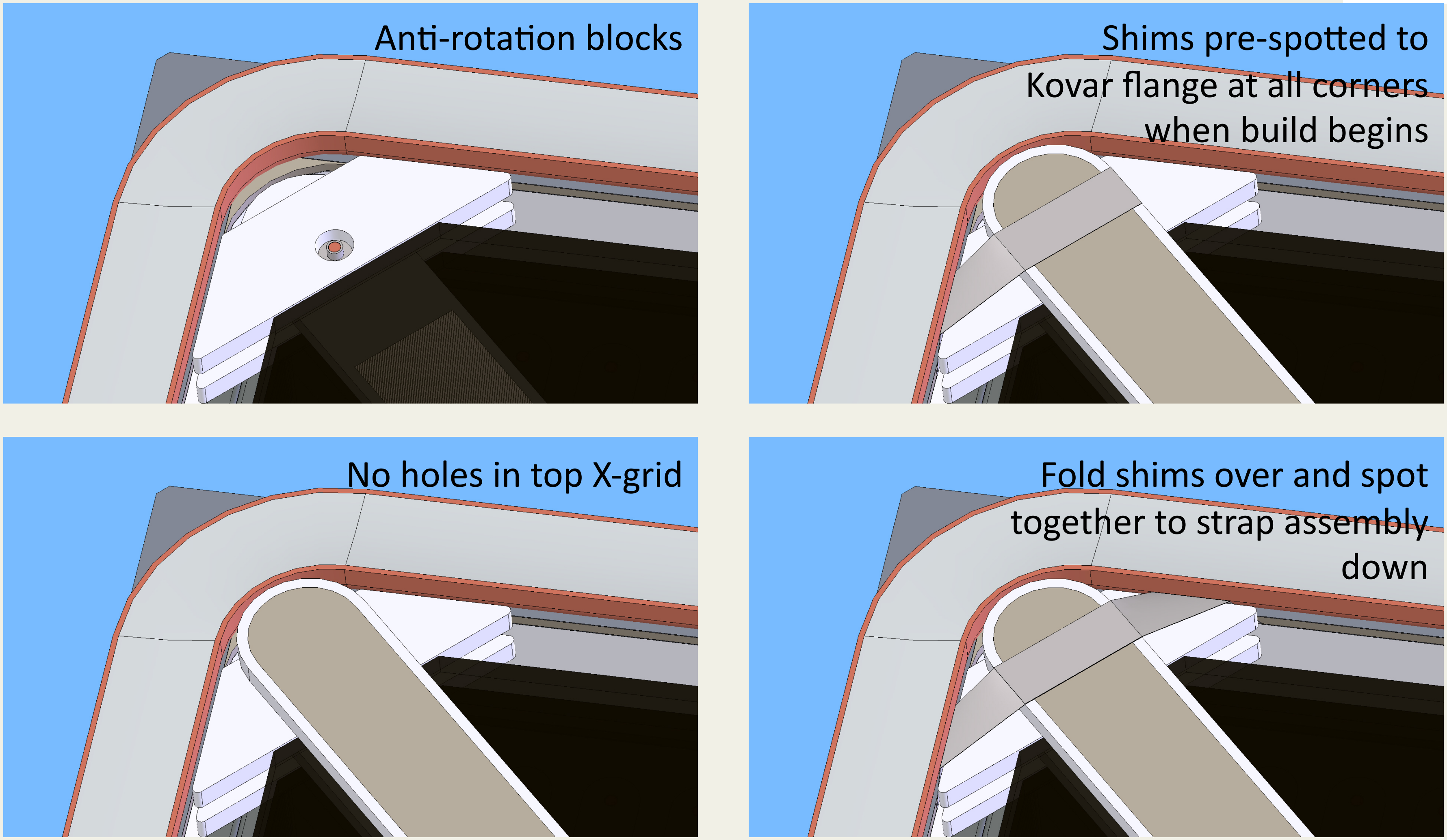
HV3 (Upper-Middle) Contact Detail



HV4 (Top) Contact Detail



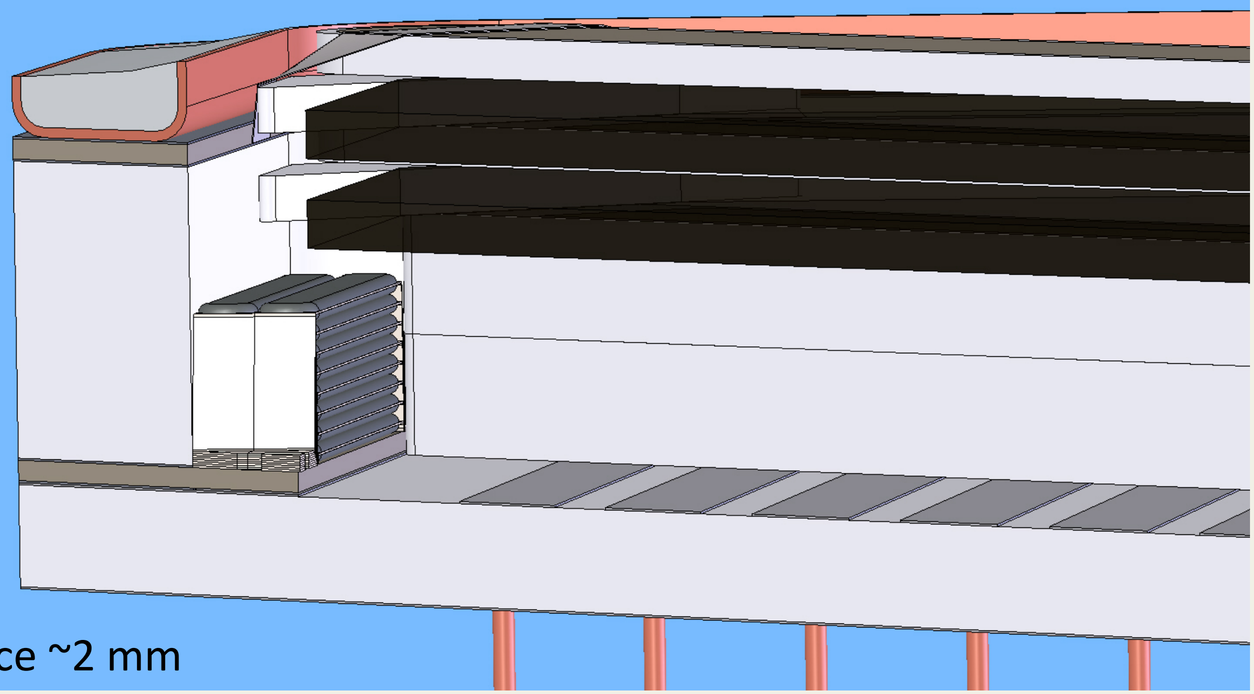
Top Lashing and Anti-Rotation Details



One More Detail

Clear and open pumping from all active areas of the MCPs

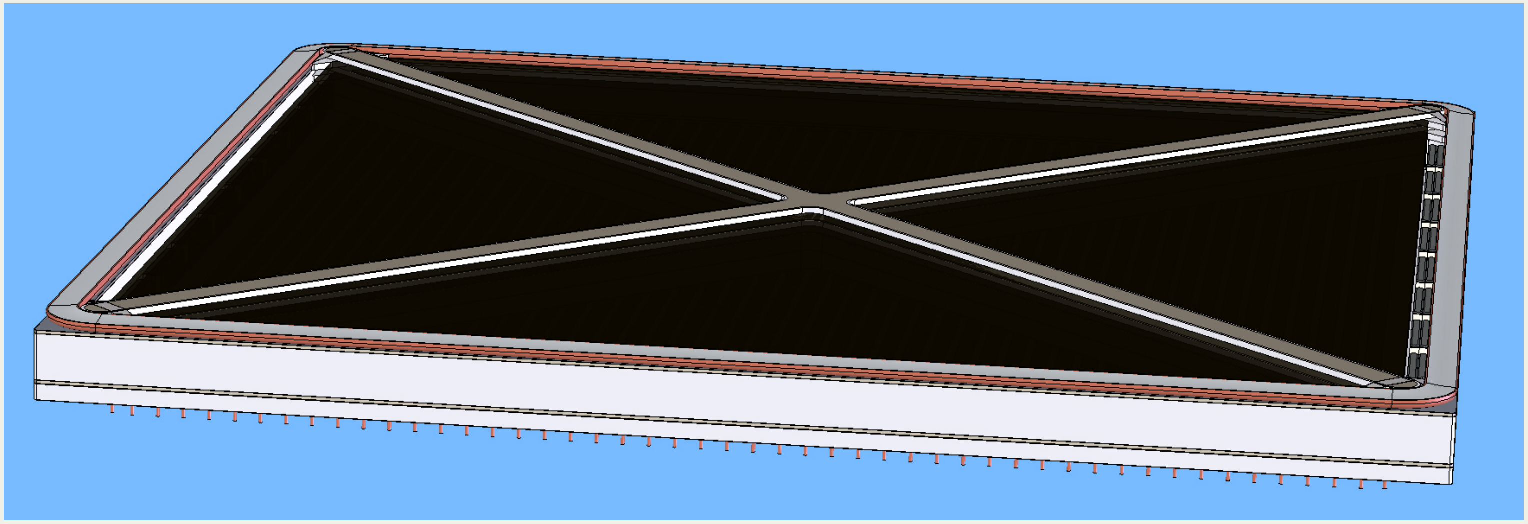
Good pump path around bottom X-grids



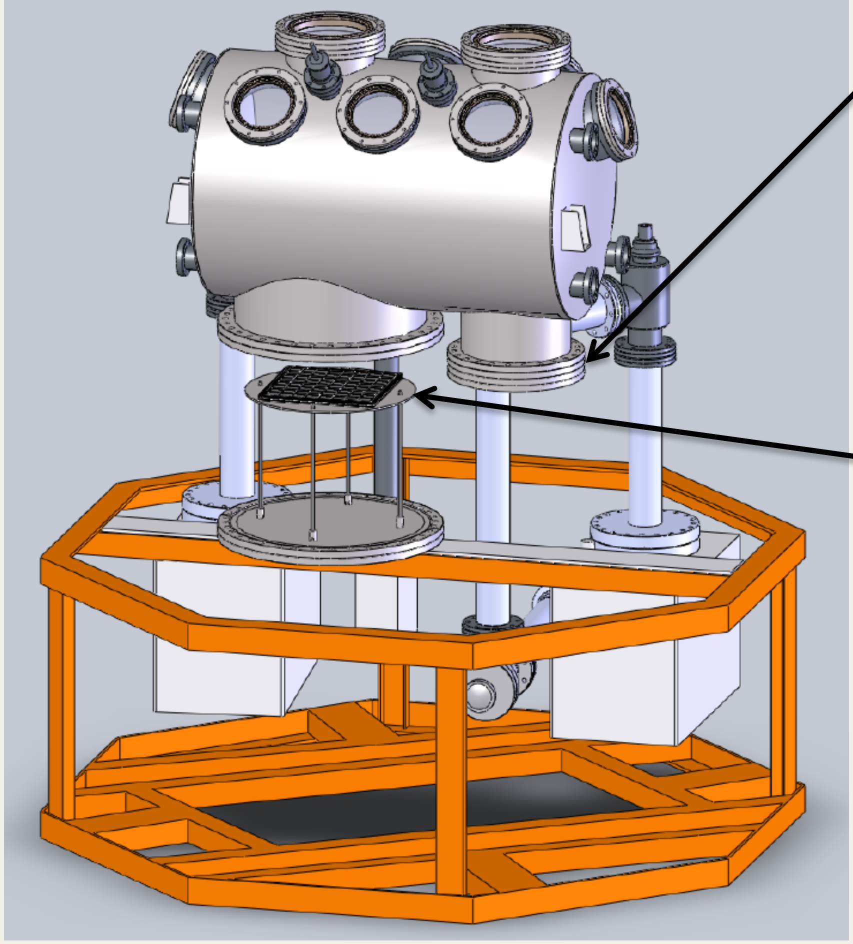
Getter HV clearance ~2 mm

Tube Ready for Processing

- Verify nothing is protruding above the seal seat
- Carefully inspect for any dust on the MCPs
- Verify electrical contact to the MCPs from the exterior pins
- Verify the MCP resistance is as expected
- Check for short circuits
- Anything else that might cause a vacuum break?
- Ready for chamber load

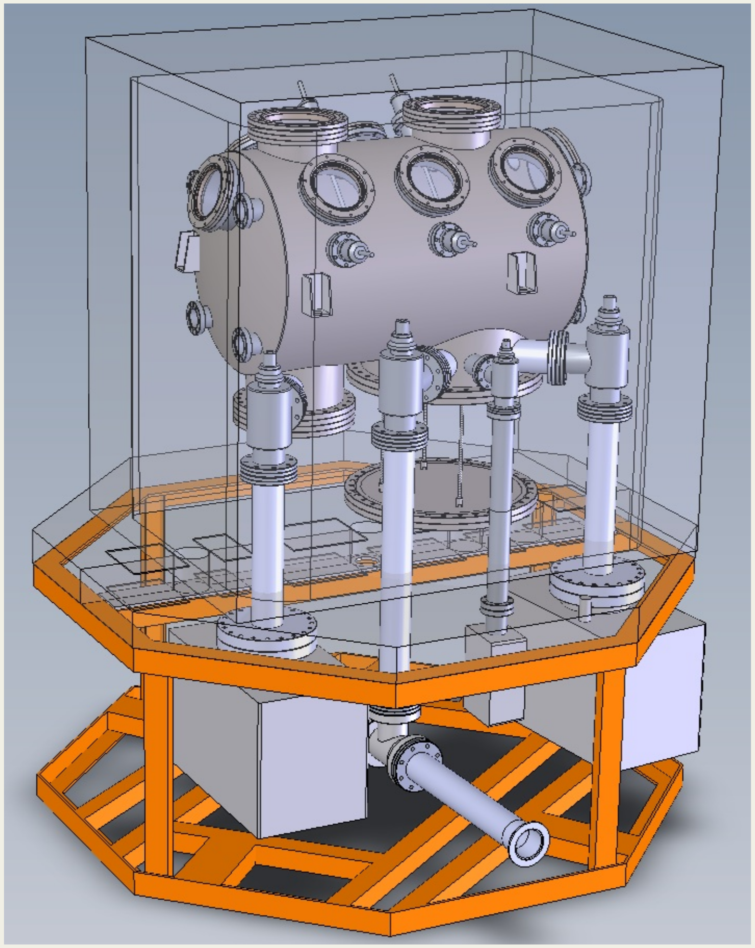


Process Chamber Load



- Cathode materials loaded in the forming well
- Tooling needed during process in the chamber
- Window on handling fixture loaded
- Tube loaded onto support flange
- Test conductivity from the tube to outside the flange
- Seal chamber and evacuate
- Functional test the detector

Tube Processing



- 350°C utility bake (12-24 hours) on turbo
- Functional test detector
- Switch to ion pumps
- Scrub the MCPs (3-4 weeks?)
- Shoot photocathode at elevated temperature (~150°C)
- Measure QE while hot
- Seal the tube on the cool down
- Once cool measure the QE again
- Last at vacuum functional test (but with window on now)
- Vent chamber
- Monitor tube for signs of leakage

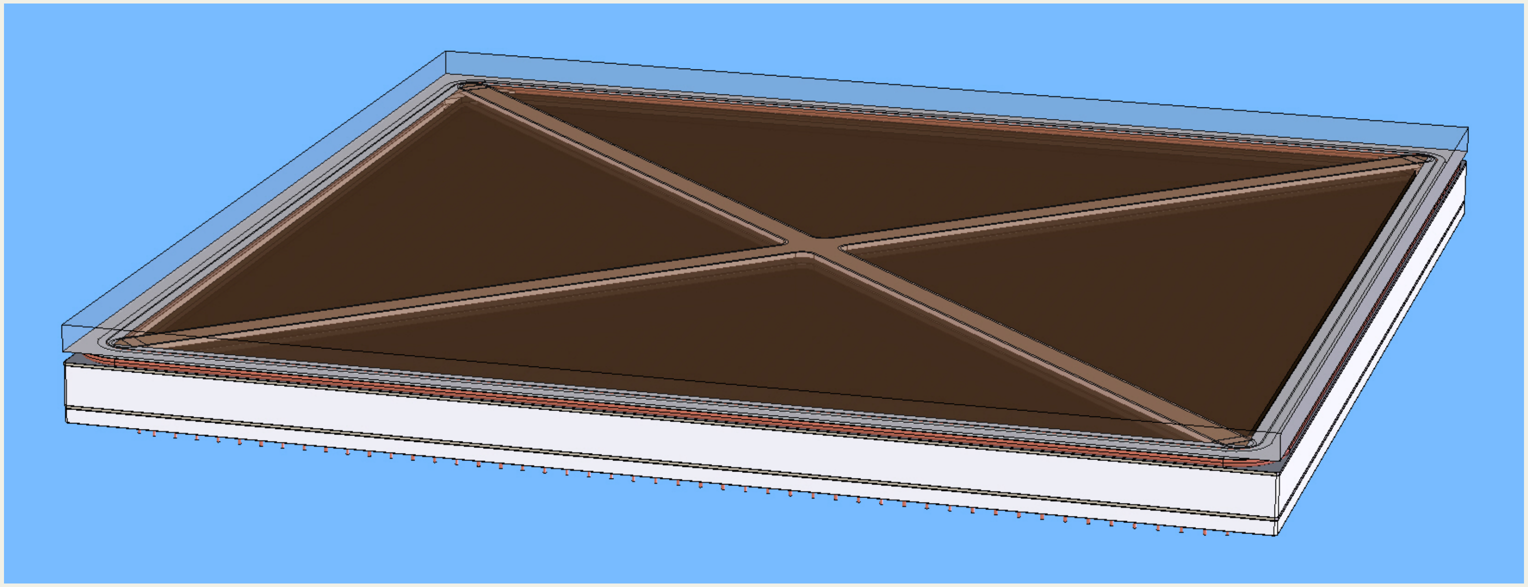
Large Tube Process Chamber

At Huntington during final fabrication

In UC Berkeley SSL high bay for fitting to the octogon cart base

Finished Tube

- Remove tube from process chamber
- Integrate with test setup for more detailed functional testing
- Perform "normal" image and gain characterizations
- Ready for integration with LAPP electronics



Concerns

- Non-flatness of ceramic parts post metallization
  - What will the anode do when metalized?
  - Can flatten with minimal force, but what happens when released?
  - Will the final assembly look like a potato chip?
- Can the MCPs support the pressure from the window and anode?
  - Need to test compressive strength of MCPs
  - Assuming compressive strength equals tensile strength (likely higher), then get FOS ~ 5 for .25" wide X-grid
  - Can widen the X-grids if needed

More Concerns

- Prefer to use Kovar indium wells, but it's unclear the fabricator can do this
  - First stamp on ½-hard Kovar (95.5 ksi tensile) didn't work
  - OFHC Cu is 34 ksi, deep draw annealed Kovar is 75 ksi
  - Is that a sufficient improvement to get the part out?
- Tolerance on getting the internal and external stack heights appropriate
  - Want the inside height ~.003" shorter (±.001" or so)
  - May require post braze machining of seal surface
- Manipulating the window in the process chamber
  - Large, heavy, square window with only a modest number of simple wobble stick manipulators (space limited)
  - Need to design a rail based shuttle system inside the tank

Even More Concerns

- Edges of MCPs may well be “hot” (high background)
  - – Block these counts by putting a square frame around one of the X-grids
  - – Best choice for this is the top anode gap X-grid
    - Doesn’t close in pumping space
    - Prevents the getters from leaning in toward active area
- Need to make a device soon
  - – Must make forward steps toward testing top seal (and braze seals) using anode blank as soon as they arrive